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FINAL REPORT

ON

JPL RESEARCH CONTRACT, TASK ORDER NO. RD-4

UNDER NASA CONTRACT NAS7-100

JPL CONTRACT 952616

"MAGNETOMETER DATA ANALYSIS"

July 30, 1969 through May 31, 1970

Brigham Young University

Provo, Utah

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

During the 10-month period from July 30, 1969 through May 31, 1970, we have made progress in a number of analysis areas. A discussion of the work performed in each of these areas is given below. The designation numbering for each work area is the same as that noted in the revised statement of work dated March 31, 1970.

(a) (1) (B) The orientation of the interplanetary magnetic field and geomagnetic activity. The results of this study include the following:

a. High geomagnetic activity occurs with both north pointing and south pointing interplanetary magnetic fields. This result differs from most previously published results concerning the "north-south" effect which ascribe greater activity to south pointing fields. Advantages of the data used in this study are that they are completely interplanetary, they are representative of different periods of solar activity (half a solar cycle), and there are no long periods of missing data.

b. Neither the MTS coordinate system nor the RTN system yielded higher correlation coefficients between interplanetary field magnitudes and indices of geomagnetic activity than did the other. In both systems these coefficients were positive but not high. Variability in the components in both systems was highly correlated with geomagnetic activity. This indicates that the mechanism relating interplanetary variables to geomagnetic activity is more closely related to variability in the interplanetary field than it is to either the magnitude or the direction of the field.

c. The gross structure of the interplanetary field did not change significantly as it was swept away from the sun by the solar wind near the orbit of the earth. This suggests that the field was approximately "frozen in" for the scale size being considered in the interplanetary plasma and that during these times there were no large scale instabilities in the solar wind in this region. Also, it indicates that magnetohydrodynamic waves which might exist in the interplanetary medium did not significantly change the large scale field structure over these same distances.

d. The correlation coefficients are higher for the variations in the individual components than for the variations in total magnitude. This fact suggests that changes in the direction of the interplanetary field are more closely related to geomagnetic activity than are changes in the magnitude of the total field.

e. The correlation coefficients obtained using the Kn, Ks, and Km indices indicate an advantage in having separate indices for the two hemispheres as well as a world-wide index.

f. The twenty-one-hour running means indicated essentially the same types of relationships as the unsmoothed three-hour data did. However, large scale correlation is much higher with the smoothed data.

g. The result that events in K_p occurred most often when the B_M component and its derivative had the same sign is probably due to the fact that a larger amplitude of variation occurred in these cases.

h. A comparison of correlation coefficients between ap and the interplanetary field variables and K_p and the interplanetary field variables indicated that better correlation occurred between ap and most variables during the Mariner II flight and that for all three flights, ap was better correlated with field magnitude than was K_p. However, during both the Mariner IV and Mariner V flights, K_p was better correlated with the sigmas than was ap. This result stems from the fact that the amplitude of variation was greater in ap than in K_p. Also, Mariner II monitored the interplanetary field during a time of high solar activity with the result that the sigma values had greater amplitudes than during the other two flights. The magnitude of the field had a greater amplitude of variation than the sigmas did during all three flights. This result indicates that better correlation occurs when the two time series in question have nearly the same amplitude of variations. Approximately 80% of this analysis program was complete at the start of funding in July with the remaining 20% being completed during the month of August. A preliminary draft of a paper reporting this analysis has been completed and is presently going through final iteration.

(a) (1) (C) A statistical study of the relationship between flare producing regions on the sun and earth observed cosmic ray variations.

Eleven years of data (mid 1957 to mid 1968) on all flares such as importance, solar latitude and projected central meridian passage as well as the daily neutron monitor counts from seven stations (Thule, Mawson, Resolute, Churchill, Wilkes, Ellsworth, and Mirny) have been keypunched for computer analysis. All of these data have been plotted in parallel and a visual correllative survey completed. The results of this analysis are in general agreement with the idea that flare producing regions, rather than individual flares, are related to cosmic ray decreases as outlined in several of our previous papers.

This program was started and carried to about 50% completion under this contract. The final results of this study will be reported in a paper to be submitted for publication at a later date.

(a) (1) (D) Statistical interrelationships among solar wind parameters and between the solar wind and field variables and geomagnetic activity.

Using the Mariner II data, scatter plots have been made for T_p and log T_p versus σB_{TN}, σB_R and σB_{TNR} as well as for $\theta = \frac{(2kT_p)}{V^2}$ versus these same field variables. These plots have been done in blocks of several days; the days were chosen as to the manner in which the velocity and/or density was changing (i.e., leading and trailing edges of streams, etc.). The plots show that the relationship between these plasma and field fluctuation variables changes from one leading edge to the next, --with some leading edges exhibiting good correlation, others very poor. The leading edge occurring on days 280-281 exhibited the best linear relationship between variables studied. We have also computed the correlation coefficients among three-hour averages of the solar wind and field parameters for days 241-304 with the following partial results:

T_p vs. σB_{TN}, 0.43; T_p vs. σB_R, 0.21; θ vs. σB_{TN}, 0.31; θ vs. σB_R, 0.24; V vs. σB_{TN}, 0.48; V vs. σB_R, 0.23. These are maximum values regardless of lag. A partial list of the correlation coefficients relating the 3-hour solar wind and field parameters to the geomagnetic Kp and ap indices include: V vs. Kp, 0.50; V vs. ap, 0.43; σB_{TN} vs. Kp, 0.37; σB_{TN} vs. ap, 0.34; Tp vs. Kp, 0.40; θ vs. Kp, 0.20. Note that using the 3-hour values, the velocity is more highly correlated with Kp than $\sigma B_{T,N}$, while using the 21-hour smoothed values, we found the opposite to be true. This probably gives us some idea concerning the effective scale sizes in the wind and the response of the geomagnetic field.

(a) (1) (E) Correlation between large-scale photospheric magnetic fields and the interplanetary magnetic fields as measured by Mariner V.

The reduction in funding cut this analysis program rather severely, and we were only able to compute the correlation coefficients corresponding to that suggested by a stream or nozzle type of relationship. As was the case for the Mariner IV program, the correlation coefficients were quite low.

(a) (1) (F) An investigation of the relationship between the variations in the solar wind parameters and those seen in the brightness temperature of the sun as measured from earth at 9.1 cm. wavelength.

In this analysis, we have assumed a simple model for the solar corona and chromosphere, used the equations for the polytrope model of the solar wind and computed the fractional change in the 9.1 cm. brightness temperature utilizing the measured values of the solar wind velocity and density obtained from Mariner II.

Using the polytrope model, where

$$T\ (r) = C\ (N(r))^{\alpha - 1},$$

Parker (1969) finds that near the orbit of the earth, the one fluid model for the solar wind predicts the velocity and number density to vary as

$$V = \frac{A T_o^{0.82}}{N_o^{0.13}}$$

and

$$N = B T_o^{8.4}\ N_o^{0.93}$$

where T_o and N_o are, respectively, the temperature and density values near the base of the corona. If one assumes such relationships, then fractional changes in the coronal values can be obtained, in principle, from changes in N and V, i.e.,

$$\frac{dT_o}{T_o} = 0.070\ \frac{dN}{N} + 0.50\ \frac{dV}{V}$$

and

$$\frac{dN_o}{N_o} = 0.44\ \frac{dN}{N} - 4.53\ \frac{dV}{V}$$

or, alternately,

$$\frac{dN}{N} = 8.4\ \frac{dT_o}{T_o} + 0.93\ \frac{dN_o}{N_o}$$

and

$$\frac{dV}{V} = 0.82\ \frac{dT_o}{T_o} - 0.13\ \frac{dN_o}{N_o}$$

Using Mariner II data, the ratio Bv/Av, where

$$Av = 0.82 \; dT_o/T_o$$

and

$$Bv = -0.13 \; dN_o/N_o \, ,$$

is generally much greater than 1. We interpret this to mean that decreases in the number density in the lower corona correspond to increases in V near the orbit of earth rather than increases in coronal temperature. One finds it much easier to relate velocity structure to features on the sun in this manner. We find the fractional change dT_o/T_o to be much smaller than dN_o/N_o, many times the former being only 10^{-2} the latter. It therefore appears that the polytrope model is not consistent with the suggestion that is often made that high temperature regions in the corona are the source of high velocity streams in the solar wind, --rather that low density regions are. This can be seen in Figure 1 where the respective wind and corona variables for days 242-251 of the Mariner II are plotted.

If the brightness temperature observed at 9.1 cm were due entirely to coronal radiation, then on the assumption of an optically thin isothermal corona, such that

$$\int T_o e^{-\tau} d\tau \rightarrow \tau \, T_o$$

where

$$\tau = \frac{KN_o^2}{T_o^{3/2}} \int \left[f(r)\right]^2 dr$$

(i.e., N(r) in the corona given by $N(r) = N_o f(r)$), then

$$\frac{dT_B}{T_B} = 2\frac{dN_o}{N_o} - \frac{1}{2}\frac{dT_o}{T_o}$$

i.e., one could check directly the validity of the polytrope model by computing $\frac{dT_o}{T_o}$ and $\frac{dN_o}{N_o}$ from $\frac{dV}{V}$ and $\frac{dN}{N}$, then computing $\frac{dT_B}{T_B}$ and comparing these values to those obtained from the 9.1 spectroheliograph data taken daily at Stanford. The above equations are an over-simplification of the problem but basically illustrate the method. For example,

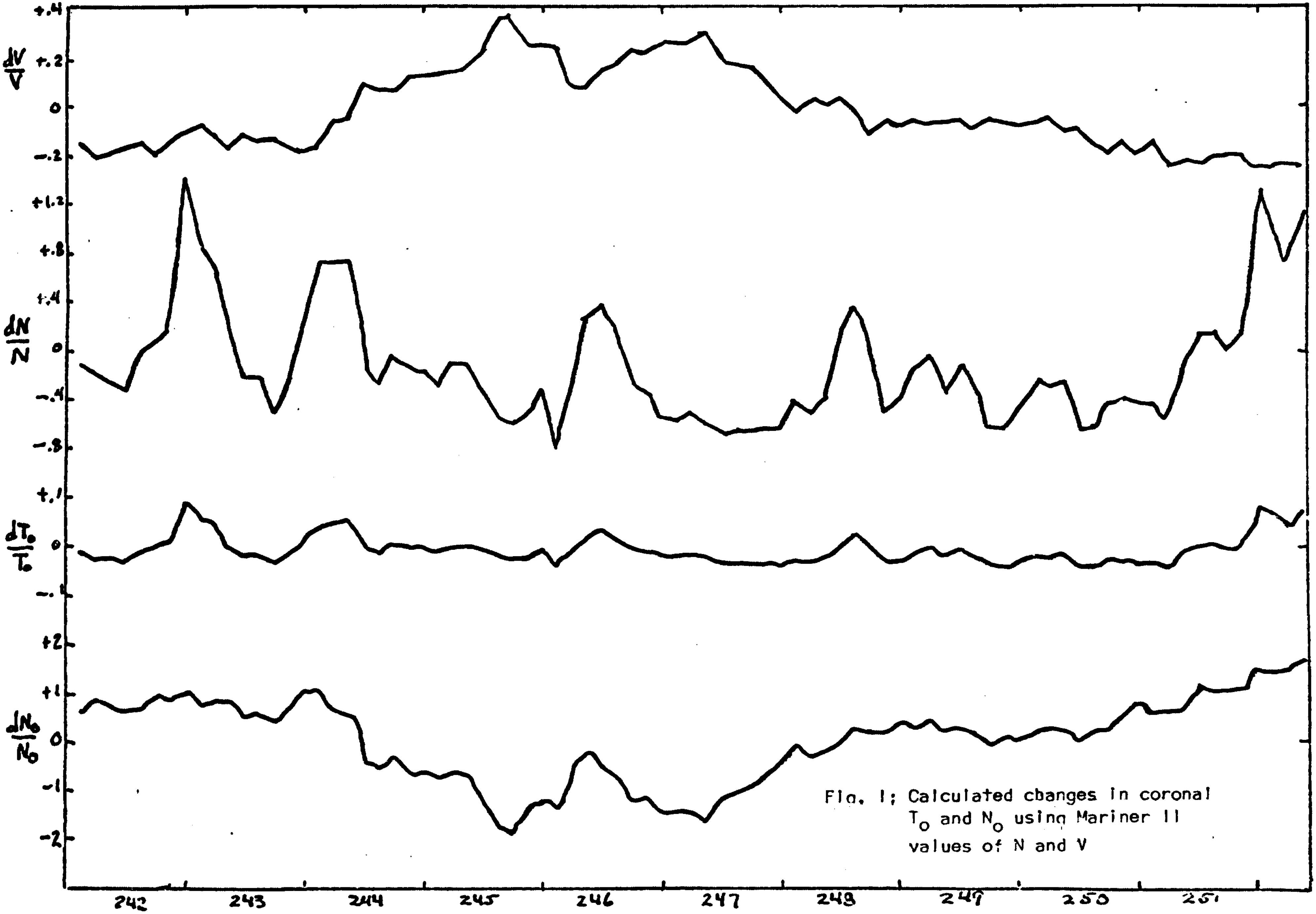

Fig. 1; Calculated changes in coronal T_o and N_o using Mariner II values of N and V we are neglecting the effects of changes in the wind parameters enroute from the sun that result from colliding streams and instabilities, as well as the chromospheric contribution to T_B. It appeared to us that such a comparison should, however, shed some light on the validity of the single fluid polytrope model.

We have computed the correlation coefficients between the measured and calculated values of dT_B/T_B and have obtained a peak value of ~ 0.4 corresponding to a lag of $\sim 3\ 1/2$ days for the 0° latitude strip. Funds ran out before we could remove the effects of colliding streams from the interplanetary data and make other obvious corrections. These results appear quite encouraging, however.

REFERENCES

1. Parker, E. N., Theoretical Studies of the Solar Wind Phenomenon, Space Science Review, 9 325-360, 1969.